



Mobile Air Conditioning Summit 2005

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Treatment of Vehicle Air Conditioning Systems in CARB's Greenhouse Gas Regulation

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Overview

- How vehicle air conditioning (AC) systems fit into CARB's GHG emission regulation
- Treatment of Direct Emissions
- Treatment of Indirect Emissions
- Final Remarks
- Next Steps



MACS Emissions



AC compressor

Direct Emissions:

*Refrigerant
release*

HFCs

Indirect Emissions:

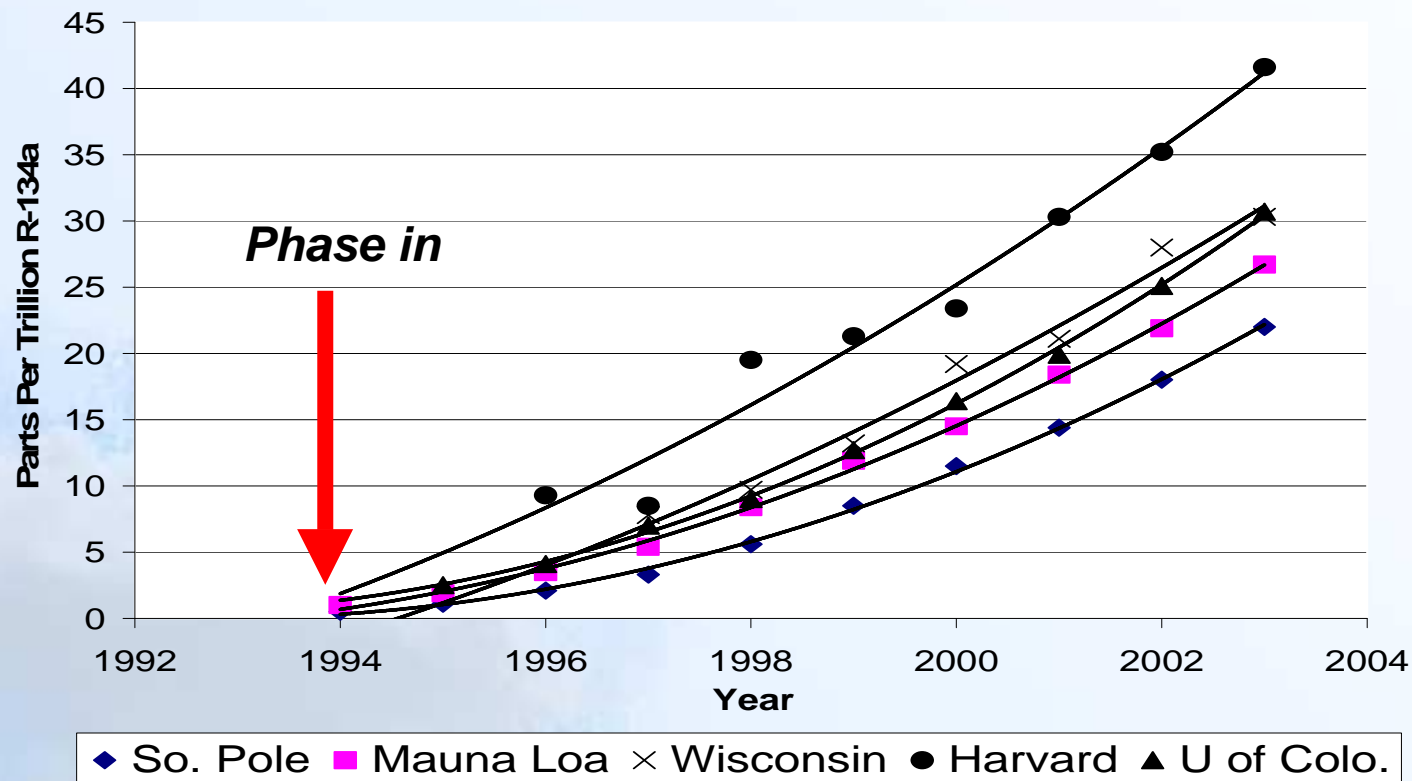
*Emissions
from AC
operation*

CO₂



Refrigerant Impact on Global Environment

Ambient R-134a Concentrations



Source: National Oceanic and Atmospheric Administration



CO₂-Equivalent Standard

$$\left(\begin{array}{l} CO_2 - equiv. \\ emissions (g / mi) \end{array} \right) = CO_2 + N_2O * GWP_{N_2O} + CH_4 * GWP_{CH_4} - AC_{allowances}$$



exhaust drive-cycle emissions

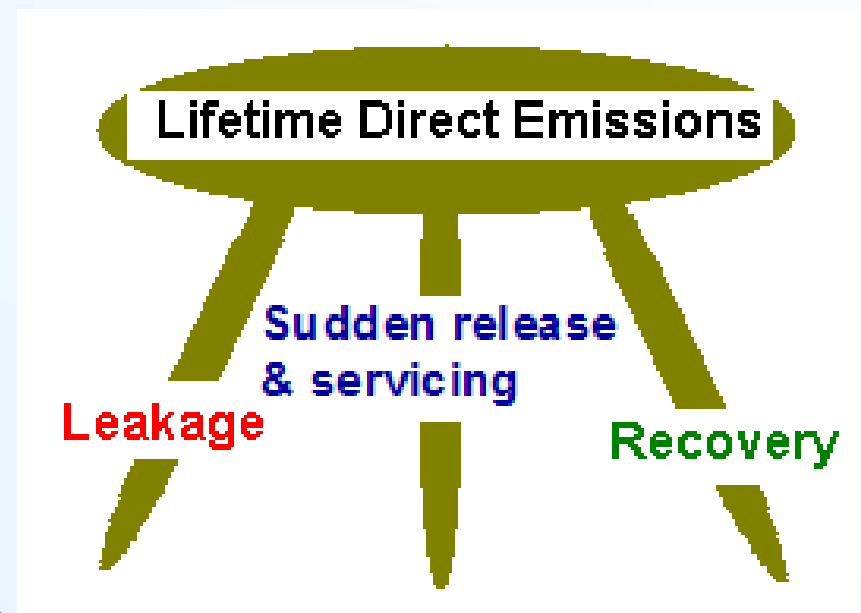
where:

- AC_{allowances} = credits for reducing direct and indirect emissions from MACS (if applicable)



Modes of Direct Lifetime Emissions

<u>Mode</u>	<u>Timing</u>	<u>When</u>
Leakage	gradual, continuous	in-use
Accidental release/ servicing	fast, discrete	in-use
End-of-life release	fast, once	post-use





California's Assessment of Direct Emissions

ANALYSIS

- Over a vehicle's life:
Emissions = *Net inputs*
= initial charge + recharges
- recovery
- Net inputs: discrete events per vehicle
- California-specific data are accessible for many vehicles

Lifetime Emissions Model*

$$LE = C * (1 - g + N*f)$$

C	-- capacity (kg)
"1"	-- initial charge
g	-- fraction of charge recovered at scrapping
N	-- number of recharges
f	-- fraction of capacity recharged

*Reference: Vincent, R., K. Cleary, A. Ayala, and R. Corey, "Emissions of HFC-134a from Light-Duty Vehicles in California," *SAE Technical Paper 2004-01-2256*.



Direct Emissions - Cont'd

Our Data Sources

Number of recharges : 12,000 vehicles in 9 fleets; surveys of 966 vehicle owners

System capacity & amount per recharge : 288 evacuations & recharges

End-of-life recovery : survey of dismantlers, discussions with US EPA & reclaimers

Lifetime : EMFAC emission model (16 yrs)

RESULTS

- 1.36 kg/HFC-134a veh life
- ~85 gm/yr/HFC-134a veh
- Or ~9 CO₂-equiv. gm/mile
- Of this, ~6 CO₂-equiv. gm/mile are due to leakage

Note: 200,000 lifetime VMT, 16 yr life, GWP=1300



Treatment of MAC Emissions in the CARB Regulation

- No changes to AC are required by regulation
- However, some AC emission reductions were assumed in establishing emission standards
- If AC emissions are not reduced
 - need additional reductions from other technologies

All alternative MAC technologies have a role in helping California meet climate change reduction goals



Direct AC Emission Provisions

Optional allowances can be obtained by:

- Qualifying as a “Low-leak AC system”
- Refrigerant substitution ($GWP \leq 150$)
- Alternative technologies
 - If reductions are demonstrated to be equal or greater than either of the above measures



Direct AC Allowances

Allowances for Direct Emission Reductions

	Refrigerant		
	Low-Leak HFC-134a	HFC-152a ²	CO ₂
Allowance in CO ₂ -equivalent grams per mile ¹	3.0 - 6.0	8.2 - 8.8	9.0

- 1 Possible allowances for reducing refrigerant leakage and/or refrigerant substitution. Note that allowances can be obtained from refrigerant substitutions that are not shown in this table. Also note that the magnitude of the allowance for each refrigerant depends on the extent to which refrigerant leakage is reduced, if any.*
- 2 The lower range of this allowance is based on HFC-152a substitution alone, and the magnitude of the allowance increases as HFC-152a leakage is reduced.*



“Low-Leak AC System” - Component Prescription

- All pipe & hose connections equipped with multiple O-rings, seal washers, or metal gaskets
- Only ultra-low permeability barrier or veneer materials for hoses in contact with refrigerant
- Only multiple-lip compressor shaft seals (with either compressor body O-rings or gaskets)



Determining Direct A/C Allowances

- “Low-leak” HFC-134a system:
 - 3 CO₂-equivalent grams per mile
 - 3 to 6 CO₂-equivalent grams per mile if reductions beyond “low-leak A/C system” are demonstrated
- Refrigerant with a GWP \leq 150:
 - 8 - 9 CO₂-equivalent grams per mile
 - Determined by equation that takes into account GWP of refrigerant and extent of leakage reduction (if any)



Indirect A/C Provisions

Optional allowances can be obtained by:

- Qualifying as an “AC system with reduced indirect emissions”
- Refrigerant substitution ($GWP \leq 150$)
- Alternative technologies
 - If reductions are demonstrated to be equal or greater than either of the above measures



Indirect AC Allowances

Allowances for Optional Indirect A/C Emission Reductions

	Qualify as an "A/C System with Reduced Indirect Emissions"	Switch to a refrigerant with a GWP of 150 or less
Allowance in CO ₂ -equivalent grams per mile	7.5 to 11	Maximum of 0.5

*The calculated indirect emission allowance is proportional to maximum A/C compressor displacement.
The range for each allowance is based on system to system variation in compressor displacement.*



Criteria for “AC System with Reduced Indirect Emissions”

- Minimizes compressor usage by managing the balance of outside and recirculated air
- Minimizes reheat by using an externally controlled compressor that may be:
 - Variable displacement
 - Variable speed (e.g. - electric motor)
 - Fully cycling fixed displacement
- Utilizes high-efficiency components



Determining Indirect AC Allowances

	Emission Factor * <i>(CO₂-equiv grams per mile per 100 cc max compressor displacement)</i>	Max Allowance <i>(CO₂- equiv grams per mile)</i>
"A/C System with Reduced Indirect Emissions"	5	9 or 11 **
Refrigerant Substitution (GWP \leq 150)	0.2	0.5

* An adjustment applies to CO₂-based A/C systems

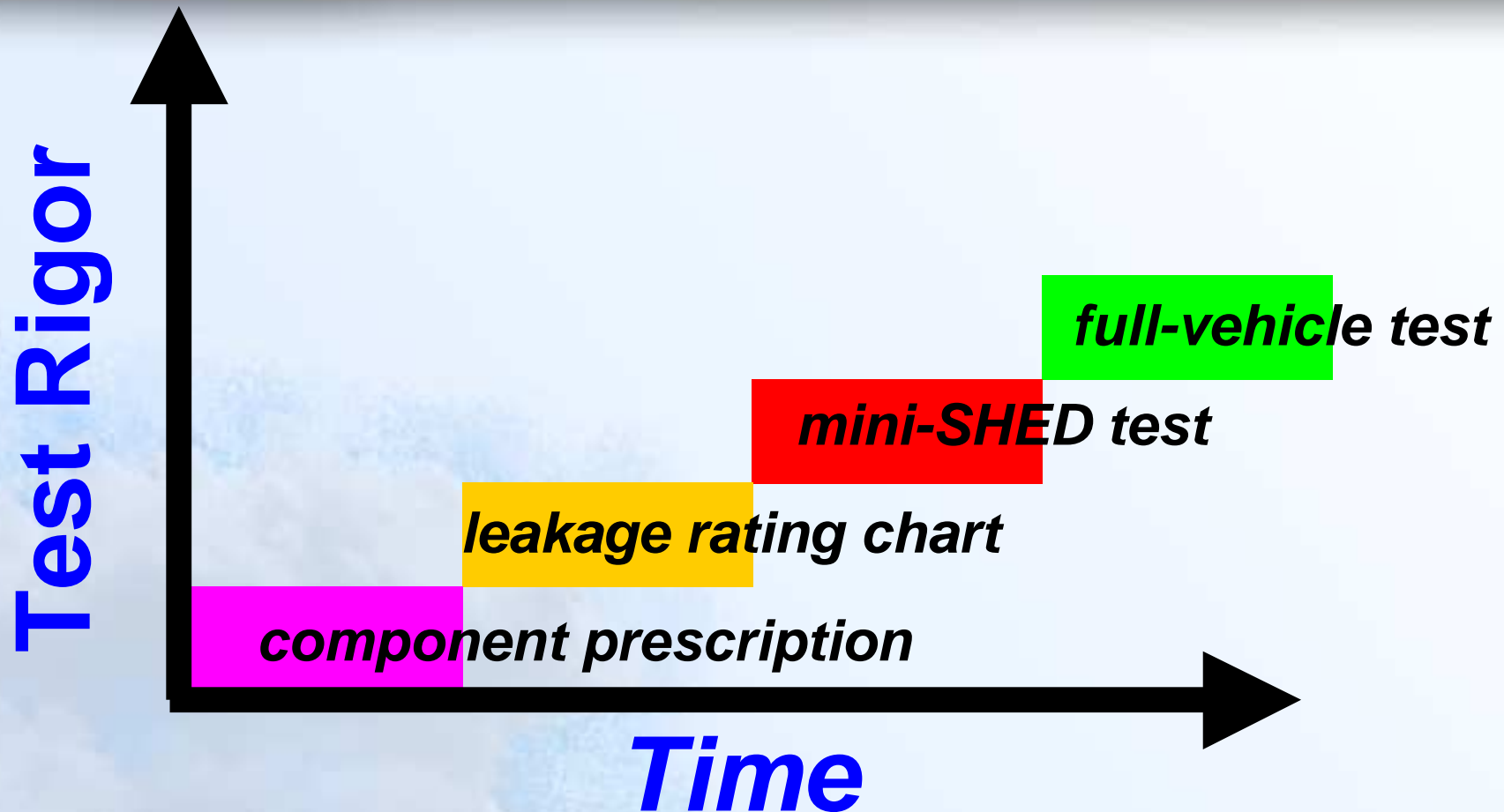
** Max allowance of 9 or 11 for a system with one or two evaporators, respectively



A Look Ahead



Qualifying as Superior MACS for Direct Emissions





MACS Rating Tool (SAE J Standard?)

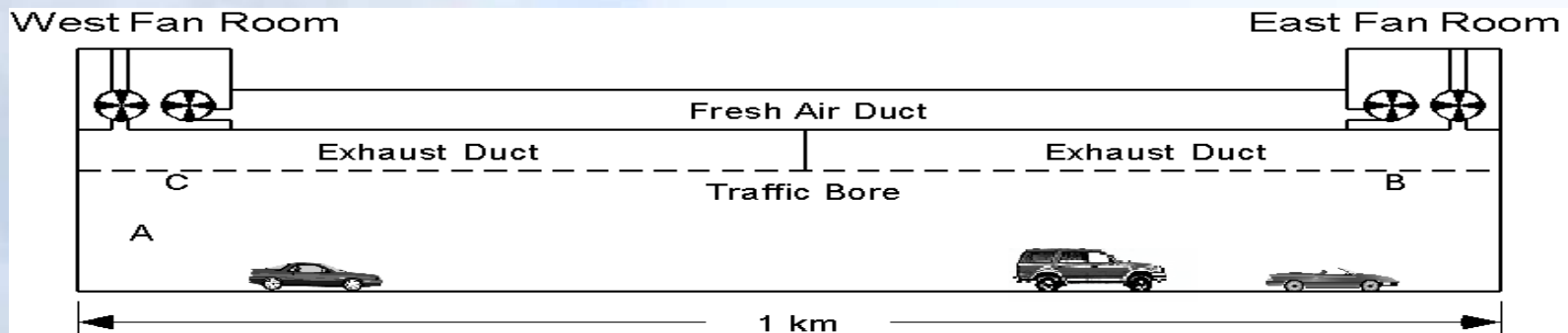
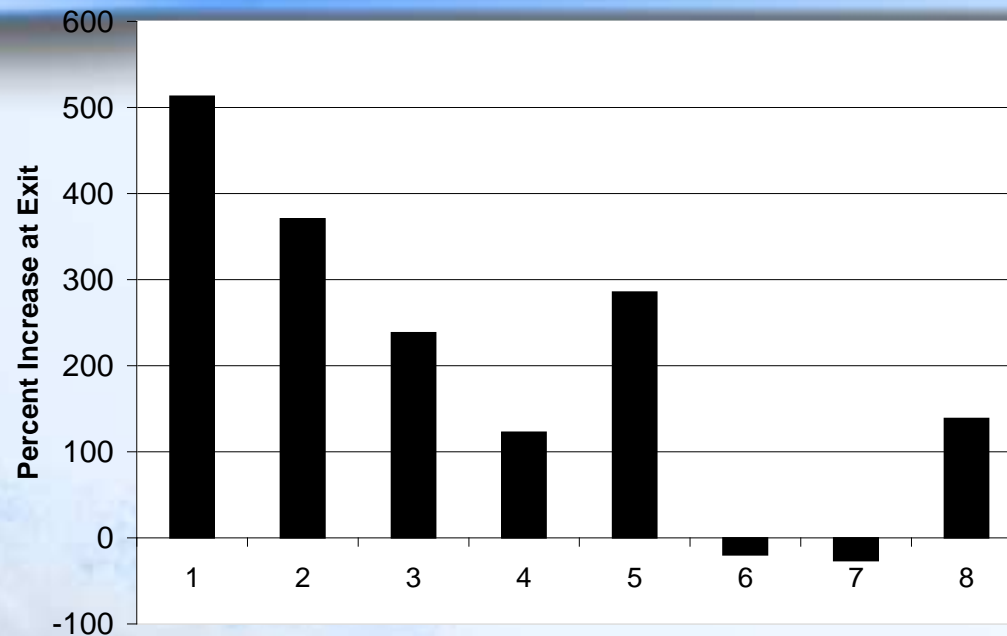
Leakage Chart

System Component Connection							Calculated Value
Fittings							
Rigid Pipe Connections and Flexible Hose Connections	Single O-ring	Single Captured O-ring	Multiple O-ring	Seal Washer	Seal Washer with O-ring	Metal Gasket	Do Not Enter Data
Total Emissions	125	75	50	10	5	1	
Number of fittings:	9	1		2			1220
High Side service port							
Total Emissions	60	60	40	10	5	1	
Number of fittings:	1						60
Low-Side service port							
Total Emissions	40	40	25	10	10	1	
Number of fittings:	1						40
PRV, Switches, Transducers							
Total Emissions	40	40	25	10	10	1	
Number of fittings:	2	1					120
						Fittings Total	1440
			Calculated Value				
Flexible Hose				Type of Hose			
Includes Hose and Hose Coupling Crimps [End Connections included in Component Connection]	Length [mm]	Diameter [mm]	Surface Area Do Not Enter Data	All Rubber Hose	Standard Barrier or Veneer Hose*	Ultra-low Perm Barrier or Veneer Hose*	Do Not Enter Data



PILOT STUDY OF DIRECT EMISSIONS OF HFC-134a MOBILE REFRIGERANT FROM A CALIFORNIA TRAFFIC TUNNEL*

Increase in R-134a at Tunnel Exit



*Reference: Cleary, K.W., A. Ayala, R. A. Harley and M.E. Gebel, "Pilot Study of Direct Emissions of HFC-134a Mobile Refrigerant from a California Traffic Tunnel," CRC On-Road Vehicle Emissions Workshop, San Diego, April 4-6, 2005.



Future Efforts

- ARB Near-term:
 - Advancing research (in-house and collaborations)
 - Requesting feedback from industry
 - Rating chart suitable optional guidance for direct AC improvements?
 - If so, ARB will work with industry to refine the chart
- ARB Mid- and Long-term:
 - Seeking collaboration to develop test methods
 - Refrigerant leakage
 - Indirect A/C emissions for whole vehicle with solar load simulation